U. S. DEPARTMENT OF AGRICULTURE
FIXED NITROGEN RESEARCH LABORATORY

A DIRECT SYNTHETIC AMMONIA PLANT

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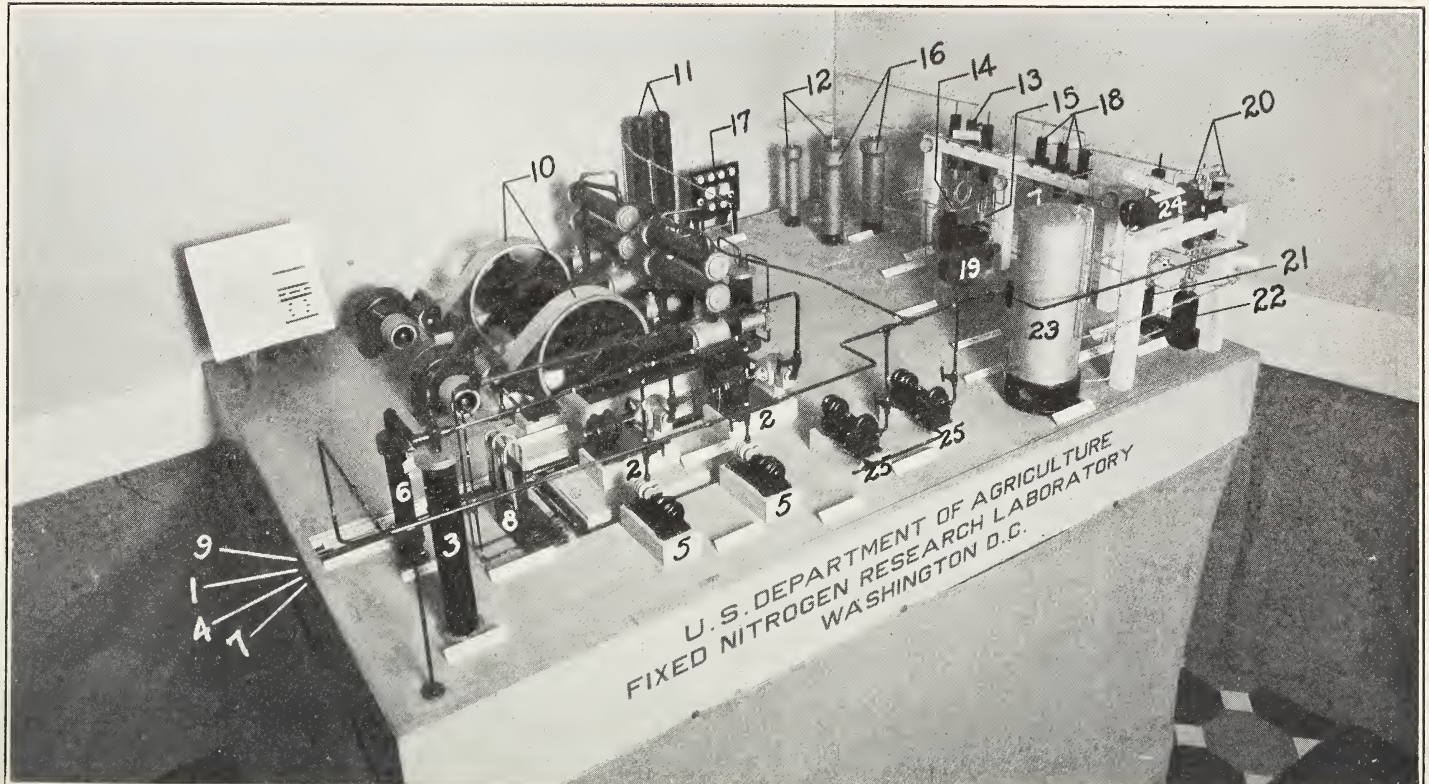
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The model on the opposite page represents a plant for the fixation of atmospheric nitrogen as ammonia by the "direct synthetic ammonia process."

In this process, the synthesis of ammonia is accomplished by passing a compressed mixture of hydrogen and nitrogen over a catalyst maintained at a relatively high temperature. The commercial installations to-day are operated at pressures within the range 100 atmospheres to 900 atmospheres and at temperatures of from 450° to 600° C. As it is not possible to effect the complete conversion of hydrogen and nitrogen to ammonia in a single pass over the catalyst, it is necessary to submit the unconverted gases to the action of the catalyst again after the ammonia formed by the preceding pass has been removed from the gas phase. This residual gas may be recirculated to the same catalyst or it may be passed on to a subsequent converter to be submitted to the action of another catalyst mass.

The large source of hydrogen is water, while the large source of nitrogen is the atmosphere. Hydrogen may be obtained from water by electrolytic decomposition, or by chemical reduction with suitable substances, as, for example, by carbon in the manufacture of water gas. Nitrogen may be separated from the oxygen of the atmosphere by liquefaction and distillation or by burning the oxygen out with hydrogen.

In the model, hydrogen, produced by a method as previously mentioned, is brought into the plant by means of main 1. It passes through blowers 2, where its pressure is increased to 2½ pounds per square inch, to burner 3. Air is introduced to the burner 3 through main 4 and blower 5, in which its pressure is raised to 2½ pounds also. In the burner the hydrogen and air mix and come in contact with a spark. Combustion then takes place with the formation of water which is removed in condenser 6, the residual gases passing out to a gasometer through the mixed gas main 7. By proper regulation of the flow of hydrogen and air to the burner, the gas coming off the condenser can be maintained as a 1 to 3 mixture of nitrogen and hydrogen, which is the ratio of these elements in ammonia. 8 is a control board, containing the volume gauges indicating the flow of gas to the burner, and the valves for regulating this flow.

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From the gasometer this mixed gas (N_2+3H_2) is drawn through main 9, to the compressors 10, where, in this system it is compressed to 300 atmospheres. The compressed gas then passes on through oil traps 11 for the removal of compressor lubricant to the purifier 12. This purifier contains a catalyst which while not an efficient ammonia catalyst is not easily poisoned. Only a relatively small percentage of ammonia is formed in this purifier. This is condensed out in the condenser 13 and collected in receiver 14. The ammonia in condensing out of the gas picks up any contained water and water vapors, leaving the residual gas which had been purified of other catalyst poisons in the purifier, pure and dry. When a sufficient quantity of liquid ammonia has been collected in receiver 14, it is unloaded to receiver 15, which when shut off from 14 is subjected to the vapor pressure of ammonia. It may then be safely unloaded to lower pressure equipment.

From receiver 14 the gas after dropping the liquid ammonia passes through converter 16. In this converter, which contains the ammonia catalyst, synthesis takes place, resulting, at 300 atmospheres and 475° C., in the effluent gases containing 20 per cent of ammonia. 17 is the control panel containing pressure gauges, temperature recorders and purifier and converter control. From the converter the gas mixture ($N_2+3H_2+20\%NH_3$) flows through condensers 18, where a small amount of ammonia is liquefied but not removed. Due to friction in passing through the catalyst mass and subsequent equipment, the gas pressure has dropped and so must be boosted up to the original operating pressure in order that the uncombined gases may be recirculated through the converter. As this gas is at this stage pure and dry, it is desired not to contaminate it by admitting oil or other such lubricant to the circulating or boosting pump. This mixture of (N_2+3H_2+gaseous NH_3+liquid NH_3) from the condensers 18 is admitted to the circulating pump 19, where the liquid ammonia acts as the lubricant. The flow is then through the condensers 20 to receiver 21, where the liquid ammonia is collected while the uncombined gases pass on to meet the make-up gas at the entrance to the converter. From receiver 21, the liquid ammonia is unloaded to receiver 22, from which it is unloaded to the low-pressure storage 23. From this storage, a part of the ammonia goes to accumulator 24, which maintains the level of the ammonia in the condensers 20. The expanded ammonia from the condensers and the surplus ammonia in the storage is then piped off to the ammonia conversion or utilization plant. 25 is water pumps for the supply of cooling water to the burner condenser 6, compressors 10 and condensers 13 and 18.

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